Renewable and Sustainable Energy Reviews 45 (2015) 1–9

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Sustainable development outcomes of coal mine methane clean development mechanism Projects in China

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ARTICLE INFO

Article history:
Received 23 August 2014
Received in revised form
8 December 2014
Accepted 4 January 2015

Keywords:
Clean development mechanism
Mining
Coal mine methane
Greenhouse gas
Certified emission reduction
Sustainable development

ABSTRACT

Since the establishment of the Clean Development Mechanism (CDM) under Article 12 of the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) there has been on-going discussion about its potential and actual effectiveness in assisting in reductions in global greenhouse gas emissions. Projects implemented in non-Annex 1 countries have had the aim to mitigate emissions of greenhouse gases and also to contribute to sustainable development. In China, a significant number of CDM projects have been implemented across a range of sectors of the economy. Although various evaluations have been made of Chinese CDM projects, one industrial sector that has received little attention has been mining. In particular, the sustainable development outcomes of Chinese CDM projects associated with methane capture and utilisation from coal mines have not been evaluated. This research has involved review and assessment of 30 Chinese coal mine methane CDM projects. The evaluation approach involved content analysis of coal mine methane CDM project documents in relation to quantitative reductions of greenhouse gas emissions and indicators of contributions to sustainable development. The sustainability indicators found to be most prevalent were safety, energy use, technology transfer and employment. Also a comparison of outcomes was made with six coal mine projects initiated under the CDM in other developing countries. Overall, it was found that only brief accounts of sustainable development goals are given in CDM documents for coal mine methane project activities and that these are arguably insufficient in detail. Although varying types of sustainability initiatives were identified, many potential areas were not. These findings have implications for the future success of CDM projects in the coal mining sector, the proposed new market mechanism under UNFCCC and similar projects being implemented under mechanisms outside the UNFCCC.

Contents

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http://dx.doi.org/10.1016/j.rser.2015.01.053
1364-0321/

1. Introduction

The Clean Development Mechanism (CDM) has emerged as the major vehicle for international trade in carbon-related instruments [1]. CDM is one of the three flexible mechanisms (CDM, Joint Implementation and International Emission Trading) under the Kyoto Protocol (Article 12) to the United Nations Framework Convention on Climate Change (UNFCCC). CDM allows emission-reduction projects in non-Annex 1 countries (countries that do not have binding emission reduction targets under the Kyoto Protocol) to provide certified emission reduction (CER) credits for partners in Annex 1 countries (countries with binding emission reduction targets under the Kyoto Protocol), each equivalent to reduction of one tonne of CO_2, which is measurable and verifiable in accordance with the approved greenhouse gas (GHG) baseline and monitoring methodology and contributes to sustainable development in non-Annex I countries [2]. CERs can be traded and sold, and used by Annex 1 countries to meet a part of their emission reduction targets under the Kyoto Protocol. The CDM is designed to give Annex I countries some flexibility in how they meet their emission reduction limitation targets. It was established in 1998 and first implemented in 2000, and has become '…an institutionalised global trading mechanism and practice' [3].

This paper reviews sustainable development contributions of CDM projects involving coal mine methane utilization in China. Also a comparison is made with six similar projects initiated under the CDM in other developing countries. Research aims were to investigate how coal mine methane projects under the CDM are contributing to sustainable development and how their contribution to sustainable development is thus reported. Additionally, assessments were made of whether information has been sufficiently documented in CDM project documents and reporting (e.g. in the Project Design Document, Validation Report and Letter of Approval) with regard to sustainable development contributions by coal mine methane projects.

The paper starts with an introduction to CDM's institutional and governance framework, CDM and GHG emissions trends from the global mining industry and the situation in China. Sustainable development aspects in the context of CDM are then discussed. This provides background for the research methods and then discussion of the research results. The final section of the paper presents conclusions and recommendations for future research.

2. CDM's institutional and governance framework

The two principal objectives of CDM projects are: assisting Annex I countries in meeting their GHG emissions reduction targets cost-effectively and promotion of sustainable development in non-Annex I countries according to Article 12(2) of the Kyoto Protocol. In order to ensure achieving both objectives by CDM, the UNFCCC Secretariat administers the CDM with the aim of interaction with all stakeholders involved in CDM project activity and in a transparent manner. Each tonne of CO_2 equivalent reduced in a developing country from a registered project, after fulfilling all the requirements for certification as one CER at the UNFCCC Registry, is tradable on the carbon market.

The CDM project cycle consists of the stages of project design, project validation, registration, monitoring, verification, certification and issuance of CERs according to CDM Modalities and Procedures (see Fig. 1). At the 7th UNFCCC Conference of Parties (COP7), the Marrakech Accords were achieved to pave the way for

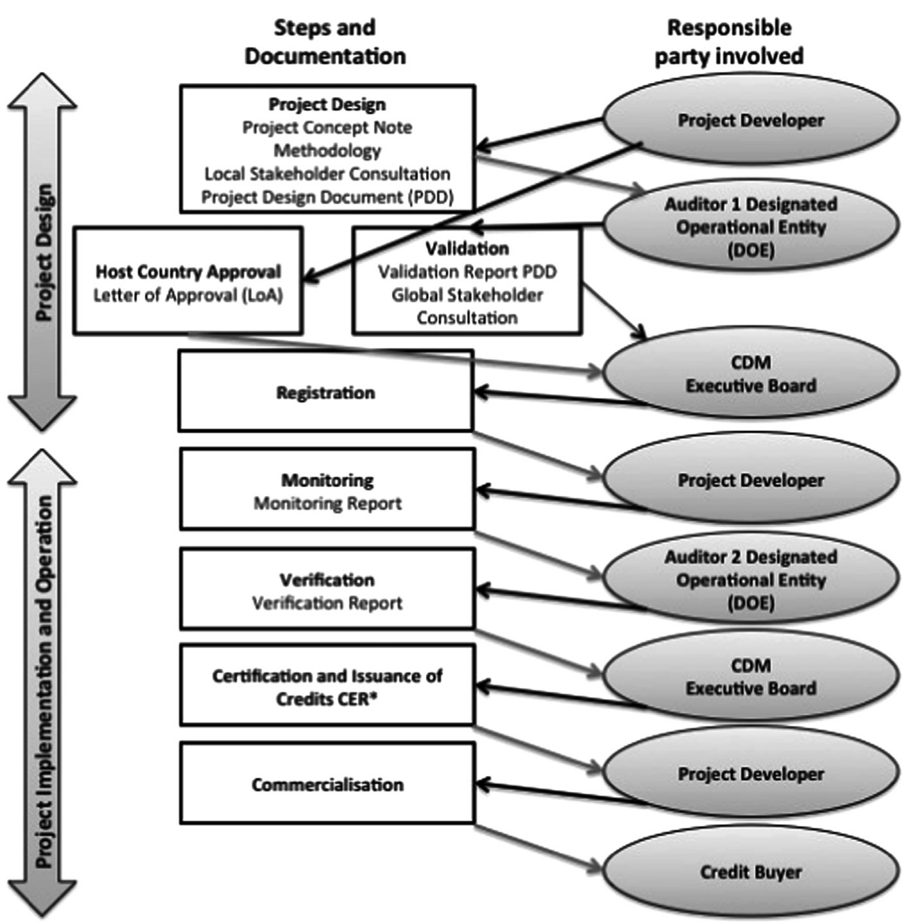

Fig. 1. The CDM project cycle modified from CORE [10]. *CER – Certified Emission Reduction unit.

the implementation of Kyoto Protocol and CDM. After this, a CDM EB (Executive Board) was established to define the detailed rules for the CDM project cycle and to accredit Designated Operational Entities (DOEs) for validation, verification, and certification of proposed CDM project activities. The overall architecture of GHG accounting and assurance requirements under CDM has been described by Uddin and Holtedahl [4].

The DNA (Designated National Authority) for CDM is responsible for providing a Letter of Approval for each project according to CDM Modalities and Procedures. The institutional structures of several DNAs in a number of non-Annex I countries have been studied by Uddin et al. [5]. While one of the main objectives of each of the DNA is to provide the Letter of Approval, their policy frameworks vary significantly in regard to institutional set-up, consideration of sustainability when assessing potential CDM projects and overall requirements in each non-Annex I country.

The policy framework for the DNA in China was set-up in accordance with China's National Coordination Committee for Climate Change (NCCCC)'s 'Interim Measures for Operation and Management of CDM Projects' 2004 [6] and as amended in 2005 to become the 'Measures for Operation and Management of Clean Development Mechanism Projects' [7]. These policy measures provide a clear description of the requirements for eligibility of a project owner, intuitional arrangements for project management, documents needed for submission, detailed procedures for obtaining a Letter of Approval and the priority areas for CDM activities in China [8]. An Inter-Ministerial body called 'The National CDM Board' was formed as policy reference actor for review of CDM applications, while the National Development and Reform Commission (NDRC) was identified as the DNA [9], which is in charge of the evaluation and monitoring of CDM projects [6].

Project developers (also referred to as project participants) design and implement project activities in non-Annex I countries. They include large development and investment banks, and members of the private or public sector from Annex I countries. In the context of China, project developers have local partners in accordance with a 51% ownership rule (which states that the share of local ownership for each CDM project must be at least of 51% of the total) and local content requirements (which establish the percentage of locally manufactured equipment that is compulsory within each CDM project) that aim to guarantee business opportunities for Chinese stakeholders in the application of the CDM [6].

While GHG reduction quantities are measureable, the sustainable development objectives of CDM are more difficult to assess at the project level due to lack of clear procedures and well-tested evaluation guidelines. Confirmation from a host country that a CDM project contributes to sustainable development is a requirement for validation of CDM projects by DOEs. However, it entirely depends on the requirements of host countries as to the manner in which sustainable development is accomplished from CDM project activities. To ensure the achievement of sustainable development of CDM projects and robust collaboration among the different stakeholders involved, at least two rounds of stakeholder consultation processes are required to be performed for every CDM project. This includes local stakeholder consultation during the project preparation and global stakeholder consultation during the validation process.

CDM projects also contribute to sustainable development at a global level as a 2% levy on CERs issued for each CDM project is directed to the UNFCCC Adaptation Fund. This Fund finances climate change adaptation projects and programmes for developing countries that are vulnerable to the adverse effects of climate change [2]. This type of levy is important as it ensures that there are adaptation outcomes from mitigation projects.

In China, as well as the UNFCCC's Adaptation Fund i.e. a 2% CDM levy on issued CERs, an additional Chinese Special Government Levy is collected on CERs sales associated with Chinese CDM projects set at 2% for priority area projects [11]. Coal mine methane recovery and utilisation projects are included under this scheme as priority area projects [12]. This Chinese Special Government Levy is used in supporting activities on climate change including the costs of CDM project documentation preparation for projects in regions with relatively low socio-economic development, or projects with high sustainable development benefits [12] as per Article 24 of the 'Measures for Operation and Management of Clean Development Mechanism Projects' in China [7]. This sustainable development contribution is additional to sustainable development contributions that may be realised locally from a CDM project.

3. CDM and mining industry relevance

For more than two decades, climate change policy has been developed and implemented at all levels of government around the globe and across a broad range of industry sectors including coal mining. The mining industry's participation was formally acknowledged in 2009, albeit later than many sectors of industry, when the International Council on Mining and Metals (ICMM) representing 19 of the world's largest mining and metals companies called for '…comprehensive and sustained global action…to reduce the scale of human-induced climate change and to adapt to its impact' [13]. Investigation into the role of mining in addressing global environment challenges and in particular addressing climate change is thus warranted [14].

Examination of CDM projects involving mining has relevance as the mining industry is a major GHG emitter internationally contributing to approximately 2% of global anthropogenic GHG emissions [15] due to energy consumption and also methane emissions. The coal mine industry is estimated to currently contribute around 8% of total global anthropogenic methane emitted from open-cut and underground mining [16]. The ICMM has recognised opportunities for mitigation of GHG emissions via CDM projects in relation to mining exist via projects focusing on:

- methane capture and utilisation (including coal bed methane, enhanced coal bed methane, coal mine and ventilation air methane, non-hydrocarbon mining methane);
- improvement of energy efficiency of mineral extraction including efficiency of motors, equipment and lighting; and
- reduction of fossil fuel usage via fuel switching and use of renewable energy [15].

China's rapid development of its mining and also mineral processing industry has been a leading support for modernising the country's industrial system. In particular, in-country exploitation of energy (i.e. coal) and mineral resources (together with imports) have contributed to growth of the national economy, promotion of the process of urbanization and improvement of the standard of living [17]. However, as a result of the scope of coal production, China has been the world's leading emitter of, and also a leader in the recovery and use of coal mine methane for over two decades [18]. The 1996–2004 period was the first Chinese decade of coal mine (including coal-bed) methane recovery and utilization as GHG emission reductions under CDM became a new focus. From 2005, the availability of sources of funding for coal mine methane recovery and utilization and especially for large CDM projects represented a Chinese 'gold rush' to recover coal mine methane and drove even stronger interest in coal mine methane project development [19]. This has led to a reduction in growth in methane emissions from coal mining in China as current projections are for emissions to reach over 22 billion m^3 of methane

(over 300 million t CO_2 equivalent) in 2015 [20]. By way of comparison, methane emissions from coal mining in China were estimated about 21.3 billion m^3 in 2009, which was around 1 billion m^3 higher compared to methane emissions in 2008 [21].

By the end of 2012, China had hosted nearly half of the CDM projects developed globally and almost all the CDM projects associated with coal mine methane [16]. As of 11 October 2012, a total of 59 CDM projects associated with the coal mine methane including around 50% of all registered CDM projects by UNFCCC were in China. These coal mine methane projects were expected to generate around 26 million CERs per annum (i.e. reduce 26 million t CO_2) compared to around 1 billion CERs obtained from implementation of 4941 CDM projects globally (as of 2012) [16]. Thus CDM projects implemented in the coal mine methane sector appear to be very effective in reducing emissions of GHGs. While management of coal mine methane has been an important safety issue for the coal mining industry now reduction of GHGs has become another imperative [22].

As CDM projects are expected to contribute to sustainable development, this research for this paper involved investigation of the sustainability outcomes of coal mine CDM projects and well as the methane reductions. There is a substantial body of literature on understanding and uncovering the complex social, environmental and economic impacts of mining (e.g. Kemp, Dupuy and Jenkins) [23–25]. In addition, a number of studies have reviewed opportunities for renewable energy as an alternative energy sources in mining/mineral industries for example, global potential of renewable energy in minerals industry is reviewed by McLeean et al. [26], renewable energy sources for remote mining sites by Paraszczak and Fytas [27] and potential for carbon emission reduction using solar PV for the mining industry in China by Wang and Taplin [28]. Sustainable development in the context of CDM projects in China has also been discussed in the literature for example, technology transfer via the CDM in China by Wang [29], sustainability as determinant of CDM activity in China by Xie et al. [30], rent extraction with a type-by-type schemes – an instrument to incorporate sustainable development into the CDM focusing on China by Liu [31] and Liu [11] and employment impacts of CDM projects in China's power sector by Wang et al. [32]. However, the sustainable development outcomes of Chinese coal mine methane CDM projects have not been discussed in the literature.

4. Materials and methods

Selection of cases for this qualitative research was done in relation to the research aims, the cases' capacity to provide information on the phenomena of interest (i.e. sustainable development outcomes of coal mine methane CDM projects), analytic generalizability (rather than statistical), and reliability and accessibility of sources of information (see e.g. [33,34]). Using an evidence-based approach and providing an ex post facto evaluation of sustainable development contributions of the coal mine methane CDM projects in China, the research aim was to offer a reliable understanding of the challenges with implementation of CDM in relation to coal mine methane in China which alone hosts nearly all coal mine methane CDM projects.

Review of previous research evaluating sustainable development contributions by CDM projects, for example by Olsen and Fenhann, Boyd et al., Nussbaumer, Alexeew et al., Subbaro and Lloyd, Hultman et al., [35–40], indicates that a range of checklist and multi-criteria analysis tools and frameworks have been used. These have been used to identify the strengths and weaknesses of CDM projects and their sustainable development contributions. Indicators that have been cited in much of the CDM literature include: impact on air quality (i.e. not including GHG emissions), water, conservation of resources and landscapes, socio-economic development, stakeholder participation, energy access, employment generation and technology transfer. The UNFCCC has recently developed and released in April 2014 a CDM sustainable development tool, *Voluntary Tool for Describing Sustainable Development Co-Benefits of CDM Project Activities or Programmes of Activities*, that aims to highlight the Kyoto Protocol mechanism's contribution to sustainable development, while maintaining the host countries' prerogative to define their criteria for sustainable development [41]. This tool has been developed as part of the CDM Executive Board's aim to create more demand for CERs by nurturing policies to broaden interest and participation in the CDM. Sustainable development co-benefit areas that are specified for reporting under the tool are: Environment – air, land, water, natural resources; Social – jobs, health and safety, education, welfare, growth, energy, technology transfer; and Economic – balance of payments. However, application of this tool to assess sustainable development impact by CDM project participants has been very limited to date due to voluntary nature of the tool and its very recent release.

To date, GHG reductions and sustainability in coal mine methane projects (considering full lifecycle of the mine e.g. construction, implementation and mine-closure) developed under CDM have not been researched apart from an overview of the benefits of CDM (covering theoretically all CDM sectors – energy, industry, construction, transport and waste) presented by UNFCCC [42] and the inclusion of two mining projects in the study of impact of CDM on sustainable development by the Energy and Resources Institute (TERI) [43]. These studies warned that there is no clear guidance on the impact of sustainable development on CDM projects. Hence, review of the effectiveness of CDM e.g. in the context of sustainable development in coal mine methane projects has the potential to contribute to future national and international climate change mitigation policy development.

4.1. Selection of coal mine methane CDM projects

This study has focussed on the status of CDM projects associated with mining as at October 2012. The UNFCCC – CDM website (http://cdm.unfccc.int/) was used to locate current and planned CDM project activities in coal mines. It was found that there were a total of 169 CDM Mining and Mineral Production projects that had applied for validation as of October 2012 (and 175 as of November 2014). Of the 169 projects, 160 were initiated with China as the host country as of October 2012. The nine remaining projects were initiated by: South Africa (2), Mexico (2 validation status applications for the same project), India (2 validation status applications for the same project), Philippines (1) and Indonesia (2), thus totalling six projects from non-Chinese host countries. These projects were found on the UNFCCC–CDM website, through the Project Cycle Search, searching with the Validation option and selecting on the Mining/Mineral Production sectoral scope option and using 'Consolidated methodology for coal bed methane, coal mine methane and ventilation air methane capture and use for power (electrical or motive) and heat and/or destruction through flaring or flameless oxidation' as the adopted methodology.

On this basis, using the Project Cycle Search and using the Advanced Search option of the CDM database in October 2012, a purposive (or judgemental) selection of project cases was made of 30 of the registered Chinese projects and six from other countries for the research. At the time (as of October 2012), 59 projects were found with the status of *registered*, all of which were initiated by China and only six projects in other countries that were all at the *validation* stage (as of November 2014, there were 82 registered coal mine methane CDM projects in China and 1 in Mexico). The

Table 1
The 30 selected registered Chinese CDM coal mine methane projects.
Source: UNFCCC CDM internet site.

Project number	Registration date	Project name	Amount of reduction[a]	Issuance to date (CERs)
2929	30 Nov 10	SDIC Xiyang Huangyanhui CMM to Power Generation Project	281,248	
3016	17 Nov 10	Yangquan Nanmei (Group) Co., Ltd. Coal mine Methane Utilization Project	214,755	
3067	17 Dec 10	Tunlan Coal Mine Methane Utilization Project, Shanxi Province, People's Republic of China	965,239	179,688
3130	16 Dec 10	Ningxia Rujigou Coal Mine Methane Power Generation Project	462,282	287,461
3179	02 Dec 10	Jincheng Chengzhuang 18 MW coal mine methane power generation project	507,500	
3180	03 Dec 10	Malan Coal Mine Methane Utilisation Project	260,184	115,146
3194	21 Dec 10	Lanhua Daning Coal Mine Methane Power Generation Project, Shanxi Province, PR China	872,939	381,892
3195	29 Oct 10	Shaqu Coal mine CMM to power generation Phase 2 Project	1,259,567	57,401
3196	03 Nov 10	Lubanshan North and South Coal Mine Methane Utilization Project	323,261	
3200	13 Oct 10	Qinxin CMM Power Generation Project	158,269	
3219	10 Dec 10	SDIC Xiyang Baiyangling CMM to power generation project	449,997	
3266	29 Oct 10	Yangquan Yinying Coal Mine Methane (CMM) Power Generation Project of Yangquan City, Shanxi Province, PR China	150,325	
3289	29 Dec 10	Ningxia Wulan Coal Mine Methane Power Generation Project	278,665	242,579
3438	18 Nov 10	Hegang Coal Industry (Group) Co., Ltd. Coal mine Methane Utilization Project	278,665	
3499	25 May 11	Jixi Coal Mine Methane Project	1,838,575	
3503	14 Jun 11	Hebei Shengyuan Xuandong Coal Mine Methane Utilization Project – China	429,202	
3542	25 Jan 11	Sichuan Guang'an Caishandong Coal Mine CMM Power Generation Project	408,647	250,354
3661	01 Aug 11	Shaanxi Tongchuan Huachen 7 MW CMM Power Generation Project – China	157,444	
3787	20 Nov 10	Ningxia Shizuishan 4.0 MW Coal Mine Methane Power Generation Project	119,084	19,902
3876	08 Nov 11	Duanwang CMM Power Generation Project	130,002	
4084	16 Feb 11	Chongqing Datong Coal mine VAM Destruction and Utilization Project	183,881	
4098	25 May 11	Shanxi Herui Coal Mine Methane Power Generation Project	1,177,274	
4534	10 Mar 11	Shanxi Wangpo Low Concentration Coal Mine Methane Utilization Project	181,991	
4594	10 Feb 12	Shanxi Huairen Chaigou Coal Mine Ventilation Air Methane Destruction Project – China	237,615	
5026	02 Aug 11	Wuda Wuhushan Coal Mine Methane Power Generation Project – China	208,195	
5227	14 Oct 11	Jilin Hunchun Coal Mine Methane (CMM) Power Generation Project – China	130,002	
5358	22 Nov 11	Duerping Middle Station Ventilation Air Methane Destruction Project – China	253,612	
5422	02 Feb 12	Guizhou Jinqiao Coal Mine CMM Utilization Project – China	127,566	
5944	30 Mar 12	Jiada Coal Mine CMM and VAM Utilization Project	135,386	
5972	05 Apr 12	Jiangxi Leping Mining Administration Low Concentration CMM Utilization Project – China	131,967	

[a] Metric tonnes CO_2 equivalent per annum.

Table 2
The 6 selected non-Chinese CDM coal mine methane projects in the validation process stage.
Source: UNFCCC CDM Internet Site.

Period for stakeholder comment during validation	Project name	Country	Estimated amount of reduction[a]
17 Mar 07–15 Apr 07	Beatrix Methane Capture Project – South Africa	South Africa	376,060
21 May 08–19 Jun 08	Mimosa Coal Mine Methane Project[b]	Mexico	606,630
04 Feb 12–04 Mar 12	Pre Mining CMM extraction at the GEECL block in Raniganj (South), West Bengal	India	21,931,348
08 Oct 10–06 Nov 10	New Denmark Colliery CMM flaring project	South Africa	23,790
04 Mar 11-02 Apr 11	Semirara Coalbed Methane Generation Project	Philippines	385,478
09 Feb 12-09 Mar 12	WBM Coal Mine Methane Extraction Project	Indonesia	582,637

[a] Metric tonnes CO_2 equivalent per annum.
[b] This project was registered on 16 Oct, 2013 (UNFCCC#3751).

most recent 30 of the Chinese registered projects were selected as CDM requirements have been refined and have become more stringent over the last few years. Hence, selection of 30 registered coal mine methane CDM projects was representative of the more recently reported projects from the total registered projects. Selection of better performing projects which were required to adhere to more rigorous CDM guidelines was the aim. Table 1 lists details of these 30 Chinese CDM coal mine methane projects [44]. The six projects in the validation stage from other countries were included to provide a comparison between Chinese sustainable development approaches in CDM projects to those of other countries [44]. Table 2 lists details of these six non-Chinese coal mine methane CDM projects.

As shown in Table 1 significant differences in the estimated amount of CERs occur for the coal mine methane CDM projects. Likewise for non-Chinese projects as shown in Table 2 there is a wide variation in the estimated amount of CERs for different projects (the project in India stands out significantly). Overall it can be inferred from the data in the tables indicate that emissions reduction potential from coal mine methane CDM projects is significant.

4.2. Content analysis

Content analysis [45] of the Project Design Documents referring to the CDM project activities for all the projects involved (registered as approved by the CDM Executive Board and in validation stage) in the study as available online at the UNFCCC CDM Internet site was conducted for the purposes of this research.

The text of these documents was searched via key word searching for reference to sustainable development indicators. For the registered projects, Validation Reports and the Letters of Approval were also searched for sustainability references. In addition, review of the relevant literature on the sustainable development contexts of CDM has been used to enable the analysis of the Chinese government policies and institutional framework and to focus on main limits related to an evidenced-based methodology.

A comprehensive framework of sustainability indicators for the mining and metals sector has been developed by Azapagic [46], but for the purposes of this research, indicators that have been used previously for research on CDM projects were adopted to allow comparability with other CDM studies. Thus the Project Design Document, Validation Report and Letter of Approval texts were searched for a similar range of sustainability indicators those used in a CDM study conducted by Olsen and Fenhann [35].

The key word indicators searched for were grouped under *environmental benefits*, *social benefits* and *economic benefits* categories. A fourth category, *other benefits* (sustainability tax, corporate social responsibility and technology transfer) was designated to extend the search. All the sustainable development references found in the documents were inserted into an Excel spreadsheet to facilitate comparison between the different coal mine methane CDM projects.

Accordingly, the content coverage with regard to sustainability indicators was:

- Environmental benefits: air, land, water and conservation.
- Social benefits: health, welfare/safety, learning and employment.
- Economic benefits: growth, energy and balance of payments.
- Other benefits: sustainability tax, corporate social responsibility and technology transfer.

These groupings have close parallels with the new 2014 CDM voluntary tool co-benefit areas (see Section 4's introduction above) [41], but are not identical as the research was conducted prior to the release of the new tool.

The sustainability impact timeframe that was considered in the CDM project documentation for the coal mine methane projects included when the project was set up (i.e. the construction phase) and over the lifetime of the project when operational. Project closure issues and impacts were not considered, as these are not required in CDM documentation. The impacts of project construction – i.e. the impacts (beneficial and/or negative) of the setup of the project (short term) and not the overall sustainable development impacts on the duration of a full project's lifetime (long term) – are mentioned in the Project Design Document under Section D (Environmental Impacts) and Section E (Stakeholders' Comments) and in the Validation Report Chapters on: Sustainable Development, Local Stakeholder Consultation and Environmental Impacts.

The impacts during the lifetime of a project are mentioned in the Introduction of the Project Design Document usually with reference to environmental, social and technology transfer impacts. Also the Letter of Approval makes reference to the project being in line with national standards and contributing to the sustainable development of the host country, though it does not usually specify in detail what these are. The Validation Report Chapters on Sustainable Development, Local Stakeholder Consultation and Environmental Impacts also document expected impacts over the lifetime of a project. Reporting of results in the next section covers these collectively due to difficulties in separating the impacts into set-up and operational phases because of imprecision in reporting.

5. Results: assessment of sustainable development

The key word indicators of sustainable development found via content analysis for the 30 Chinese coal mine methane CDM projects and six non-Chinese coal mine methane projects were: air, welfare/safety, learning, employment, energy (electricity generation and heat production) and technology transfer. Reference to the indicator 'air' generally indicated reduction of methane (CH_4) emissions i.e. cited as a positive local air quality improvement as well as in reduction of GHG emissions. Other positive sustainability outcomes associated with air quality were reported in a few of the documents, specified as the reduction of SO_2, NO_x, coal ash and total suspended particulates (TSPs). The indicator 'welfare/safety' was noted in relation to improved 'safety on site' due to the reduction of risks with methane, as methane is removed from the underground workings. Also 'learning' in the form of training in 'safety on site' was mentioned a few times. Reference to the 'employment' indicator pointed to either employment opportunities during the construction of the project and/or during project operation. A further indicator mentioned for most of the projects was 'energy' as these projects mostly involved methane capture for 'electricity generation' and 'heat generation'. This electricity produced means that electricity sourced from grid is replaced by on-site electricity generation, which in turn reduces GHG emissions from coal-based grid electricity. The indicator 'other benefits' points to 'technology transfer' in regard to the methods of extraction and utilisation of methane for electricity generation and heat production. Indicators of sustainable development for CDM coal mine methane projects are shown in Fig. 2, where the white boxes show the indicators that were specified in the researched Project Design Document, Letter of Approval, and Validation documents and shaded boxes are those omitted.

Content analysis reveals that not all the sustainable development key word indicators exist in the CDM documents for both the Chinese and non-Chinese coal mine methane projects based on mine methane researched. One reason could be that at the time of establishment of the projects there was a lack of an approved set of sustainable development indicators for CDM governance and national CDM administration. This had implications for sustainable development in the context of social, environmental and economic and administrative perspectives. Interestingly, another omission was that the mandatory Chinese Special Government Levy of 2% on CER sales collected for sustainable development purposes was not cited in any of the CDM documents of the Chinese coal mine methane CDM projects analysed. Also the status ownership rule (share of the local ownership for each CDM project must be at least of 51% of the total) was not mentioned.

Fig. 3 illustrates the five most prevalent indicators of sustainable development that were identified in the Project Design Documents for the Chinese coal mine methane CDM projects. Energy (electricity generation) and employment were the two predominant indicators with electricity generation indicated in all 30 projects. TERI's (2012) study of 202 CDM projects found that the sustainable development indicator 'employment generation' was mentioned 80% of the time [43]. Whereas an occurrence of 29% was found in the UNFCCC's (2012) study of 3864 CDM projects. 'Employment' in CDM coal mine methane projects was mentioned as a benefit for 97% of the Chinese projects and for five of the six (83%) of non-Chinese projects [42]. Overall there was little variation in sustainability focus on energy (electricity generation) and employment between the Chinese and non-Chinese coal mine methane CDM projects. The specific norms (i.e. Chinese Special Government Levy of 2% of CERs sales and share of the local ownership for CDM project must be at least of 51% of the total) have nevertheless had the side effect of discouraging the involvement of foreign companies as direct project participants in Chinese

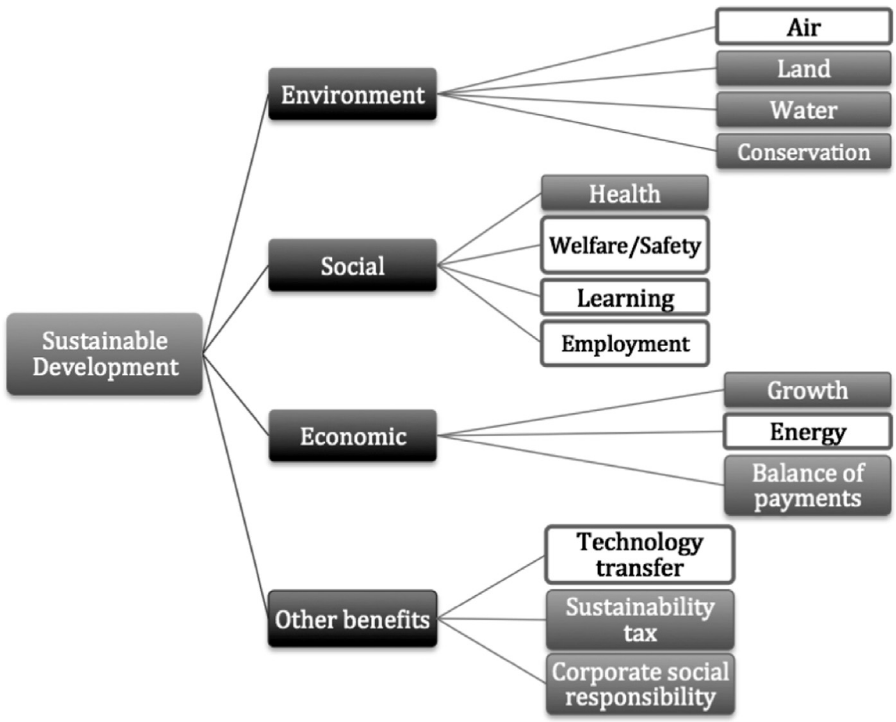

Fig. 2. Indicators of sustainable development for CDM coal mine methane projects, where the white boxes show the indicators that were specified in the content of the Project Design Document, Letter of Approval and Validation Report documents.

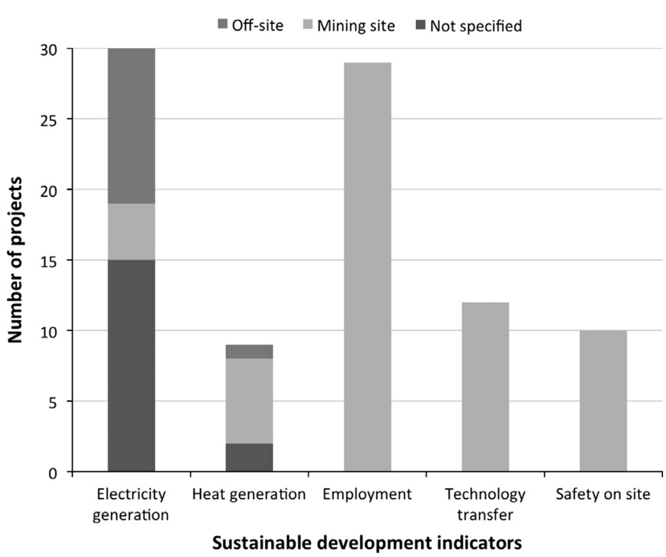

Fig. 3. Occurrence of the sustainable development indicators for the 30 selected Chinese CDM coal mine methane projects.

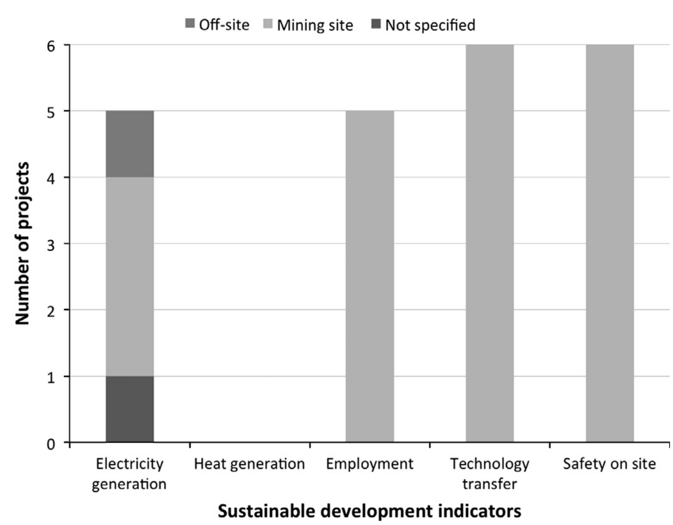

Fig. 4. Occurrence of the sustainable development indicators for the six selected CDM coal mine methane projects under the validation phase from the non-Chinese countries.

CDM projects, which in turn appeared has reduced the technology transfer impact of the CDM mechanism [6].

Fig. 4 shows the most prevalent indicators of sustainable development associated with the six non-Chinese CDM projects, where 'technology transfer' and 'safety on site' were the most significant benefits indicated. Technology transfer was reported in the Energy and Resources Institute (TERI) (2012) study to be an indicator in about 37% of the projects. However, neither of the two mining projects in the TERI study reported technology transfer in their documentation [43]. UNFCCC (2012) reported about 40% of coal bed or coal mine methane projects involved technology transfer, which is in line with the 40% of the Chinese coal mine methane CDM projects identified in this research. By contrast, 100% of the non-Chinese coal mine methane CDM projects in this research reported technology transfer [42]. This suggests that Chinese mining companies may have greater access to advanced technology or technology beyond benchmark. In the UNFCCC (2012) study about 15% of CDM projects claimed improvement in 'health and safety' for coal bed or coal mine methane projects due to lower risks of explosions from methane leakage, compared to 100% in non-Chinese projects and 33% in Chinese coal mine methane CDM projects in this research where 'safety on site' was indicated [42]. Further site investigation of the Chinese coal mine methane pre- and post-CDM project implementation would provide further understanding of this reporting.

It is noticeable that electricity generation was not as prevalent as a sustainable development indicator in the non-Chinese coal mine methane projects as it was with the 30 Chinese coal mine

methane CDM projects. Heat generation was not specified in any of the non-Chinese coal mine methane projects with most of them noting that there is no use for heat generation due to the fact that these projects were situated in warmer climatic regions. This also suggests that CDM in coal mine methane have been driven by opportunities in China to reduce use of coal-fired electricity use from grid and GHG reductions. Other countries may focus in development of future CDM coal mine methane projects on generation of electricity for self-use on site or supply to the electricity grid.

6. Discussion and conclusions

The continuity of the CDM was confirmed at the Seventeenth UN Conference of the Parties (COP17) to the Framework Convention on Climate Change in Durban in December 2011 and affirmed by Parties in COP18 in Doha in December 2012. Thus CDM will continue through the second commitment period until 2020 as a mechanism under the Kyoto Protocol. The contribution made to emissions abatement by CDM projects associated with mining (coal mine methane) in developing countries is building and has the potential to be very significant internationally in the future. Most coal mine methane CDM projects to date have been initiated and have been registered by the CDM Executive Board are located in China but projects are commencing in other countries including India, Indonesia, Mexico, the Philippines and South Africa. Also projects in Least Developing Countries (LDCs) have been foreshadowed. This is especially relevant as the European Union in their 2013–2020 EU-ETS agenda, has decided to only allow the trading of CERs that are being generated through CDM projects implemented in LDCs with an emphasis on African LDCs. The emphasis on CDM projects in LDCs indicates even further need for due attention to be given to sustainable development measures during the CDM lifecycle for projects associated with mining.

Overall it was found there was a mix of achievements associated with the CDM projects in coal mine methane researched in contributing to sustainable development. Not all likely indicators of sustainable development have been explicitly addressed in the projects' CDM reporting. These include areas of reporting such as environmental (land, water and conservation impacts), social (health), economic (growth and balance of payments) and other (sustainability tax and corporate social responsibility). However, documentation may be incomplete in some areas. Chinese Special Government Levy collected as 2% on CER sales associated with CDM projects was not mentioned for any Chinese coal mine methane CDM project.

The indicators of sustainable development found via content analysis for the 30 Chinese and six non-Chinese coal mine methane projects were: air, welfare/safety, learning, employment, energy (electricity generation and heat production) and technology transfer. Of these – safety, employment, electricity generation, heat production and technology transfer were the most prevalent. Provision of electricity may be locally off-site, on the mine site or in some cases electricity is fed into the grid. Use of heat production was limited to Chinese coal mine methane CDM projects in colder climatic zones. Technology transfer involvement was less frequents with Chinese coal mine methane CDM projects. With respect to information recorded in the CDM documents, only brief accounts of sustainable development benefits are recorded in Project Design Documents, Letter of Approvals and Validation Reports, which is arguably insufficient given the sustainable development expectations for these coal mine methane CDM projects. It is also not surprising given that there was no accepted and common standard for assessing sustainable development benefits from CDM projects and in particular those associated with coal mine methane. This has implications for the future success of CDM projects in the mining sector (especially coal mine methane), the proposed new market mechanism under UNFCCC, and for assessment of similar projects established under mechanisms outside the UNFCCC. While the CDM Executive Board and national governments ensure participation in CDM projects is compliant with guidelines, compulsory rather than voluntary use of the new *Voluntary Tool for Describing Sustainable Development Co-Benefits of CDM Project Activities or Programmes of Activities* [41] mentioned previously could enhance the sustainable development contribution of all CDM projects and those by the mining sector (especially coal mine methane). Also, a more detailed description of sustainable development goals in all CDM project documentation is warranted. However, in this paper, an attempt has been made in order to address status of sustainability in relevance to coal mine methane CDM projects. Further examination of the utility of Azapagic's [46] framework of sustainable development indicators for the mining and minerals industry could be instructive for assessment of CDM mining projects. Also the whole lifecycle of projects including mine closure [47] ideally should be considered. With regard to future research, a way forward would be to evaluate actual sustainable development achievement for coal mine methane CDM projects on-the-ground at site level taking into consideration the whole lifecycle of the mine. Also examination of new CDM mining projects that employ the voluntary tool would be worthwhile.

Acknowledgements

The research for this paper was supported with a research grant from the School of Mining Engineering, University of New South Wales. Additionally we would like to thank the anonymous reviewers of this paper for their constructive advice and reviewers of earlier conference papers on the topic presented at the 2013 World Mining Congress and the Sustainable Development in the Minerals Industry 6th International Conference in 2013. The usual disclaimer applies.

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